Residual Radiation in the Main Injector

2004 Shutdown

H^- Transport and Injection Mini-Workshop
December 9-10, 2004

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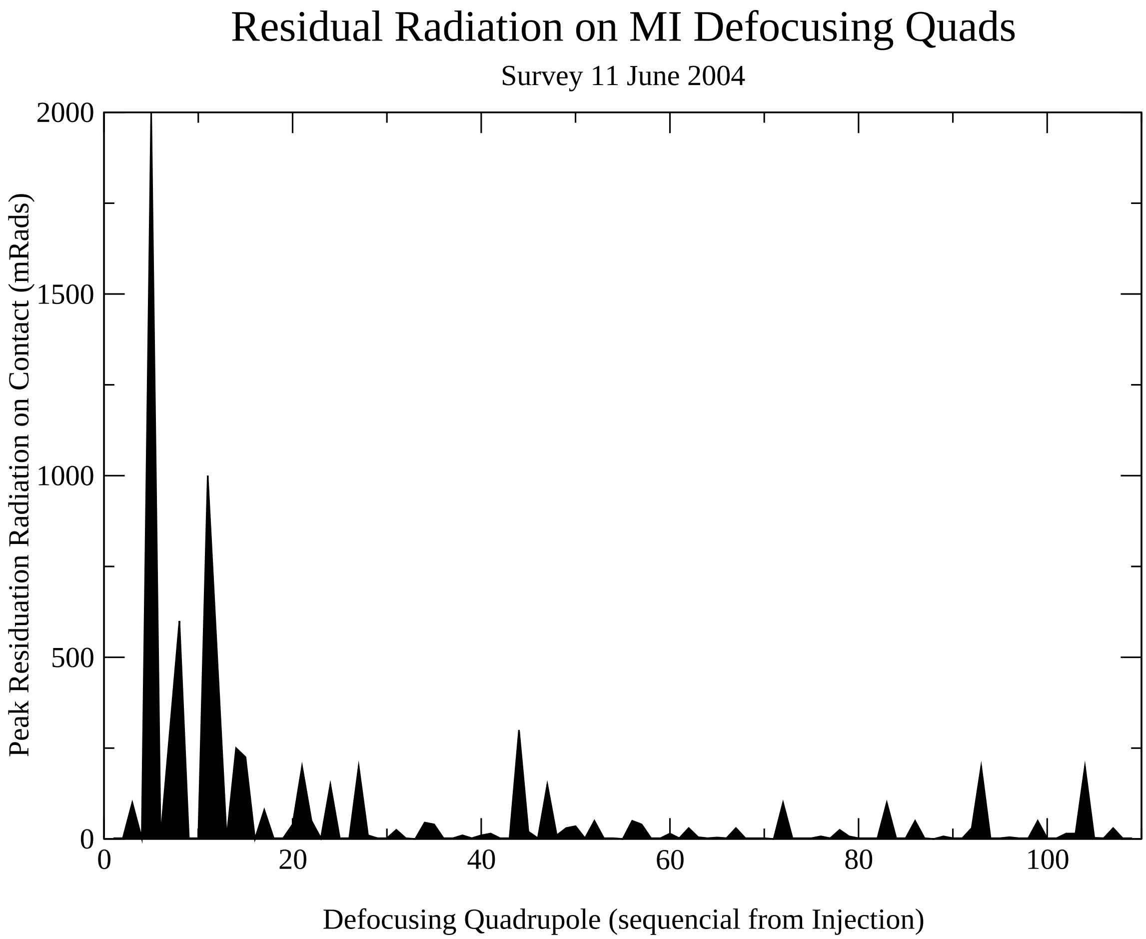
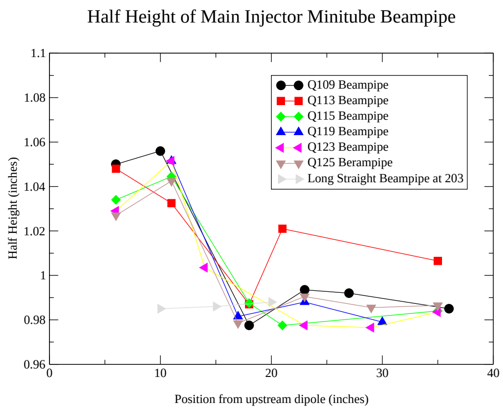
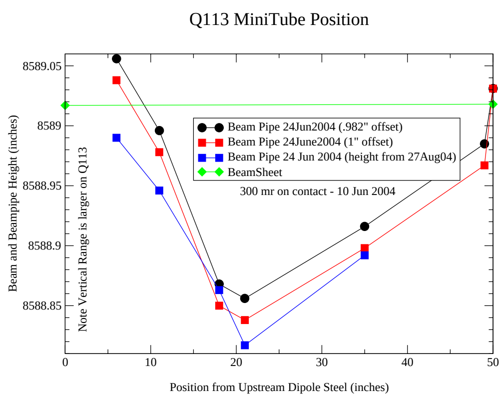
9 December 2004



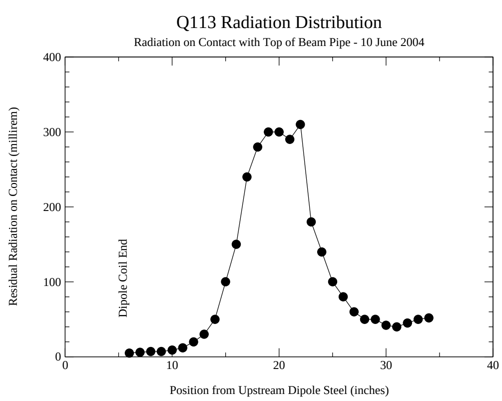
Results of Radiation Survey in June 2004
Residual Radiation after few hour shutdown
Measurements at Contact



Beam Pipe Shape in Minitube under vacuum. Left End has bellows.

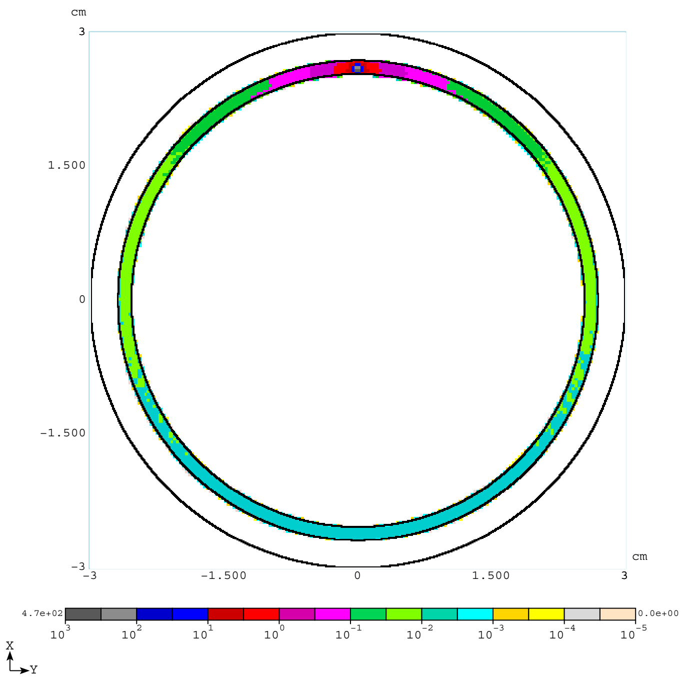


Beampipe Centerline upstream of Q113. Blue uses measured beampipe height.

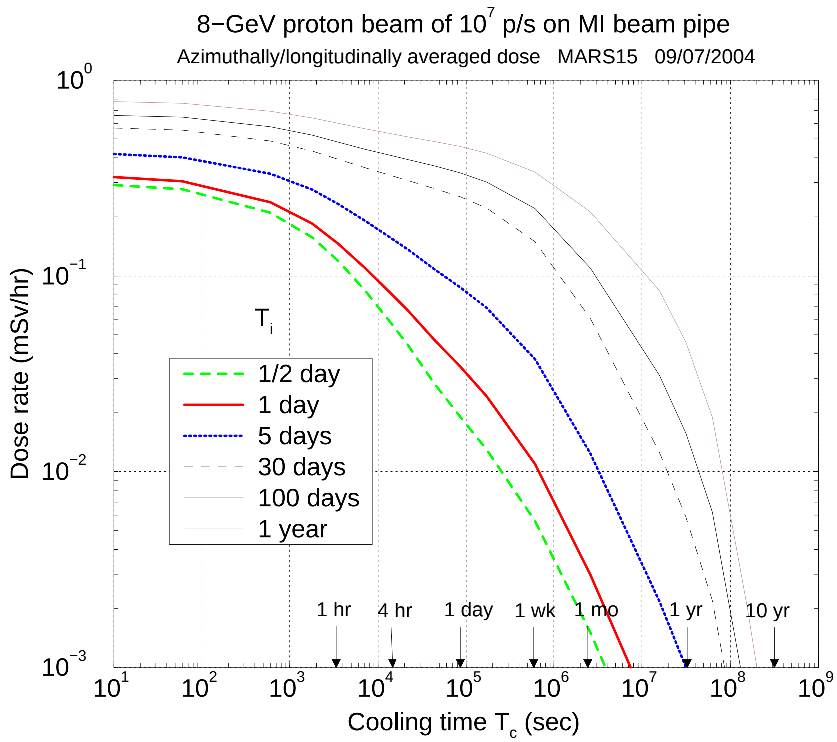


Distribution of Residuation Radiation at Q113

Photo showing beam irridation of paper tag. This is at MI401.



x-y distribution of radiation from pencil beam on round pipe
3×10^7 p/sec for 30 days with 1 day cooldown



Alternative excitation and cooldown times.

- The Main Injector at intensities of 5×10^{12} protons/Booster Batch receives an emittance (95%) of $\epsilon_V \approx 16\pi$ mm-mr.

- At $\beta \approx 55$ m at the Defocusing Quads gives a 95% beam size (half height) of 9.6 mm.

- The bare beam pipe is $2''$ full height inside the dipoles but vacuum forces collapse the beam pipe in longer sections. In regular cells, the dipole of the previous cell is followed by a bellows which rigidly supports a larger height. The transition from the bellows to the unsupported beam pipe takes place in about $6''$.
  Thus the beam pipe size gives a half height profile after subtracting 1.5 mm for the beam pipe thickness of
  23.9, 25.2, 22 mm
  These define an aperture before alignment and orbit control issues.

- The radiation survey was followed by an alignment effort. It found that the areas which had the characteristic residual radiation patten had beam pipe misaligned (always *low* by 1.5 to 2.5 mm (5 mm extreme).

- Orbit control is good. Assume an extreme and allow 2 mm for injection and an additional 2 mm for closed orbit error.

- Subtract (despite the possibility of adding or subtracting) from the 22 mm at the vacuum size minimum of the pipe height the 2.5 mm for pipe misallignment (leaves 19.5 mm) and up to 4 mm for orbit and injection errors leaving at least 15.5 mm.

The normalized beam emittance ϵ_N containing 95% of the beam is given by

$$\epsilon_N(95\%) = \beta\gamma \frac{6\pi\sigma^2(s)}{\beta(s)} \tag{1}$$

where β, γ are the relativistic factors, $\beta(s)$ is the Courant-Snyder envelope function and σ is the RMS beam size. For a gaussian distribution of beam particles, the number at radius r of the center is given by

$$dN = \frac{N_0}{2\pi\sigma^2} e^{-\frac{r^2}{2\sigma^2}}\, r\, dr d\theta \tag{2}$$

while the fraction inside radius a is

$$f = \frac{N}{N_0} = 1 - e^{-\frac{a^2}{2\sigma^2}} \tag{3}$$

All for a Gaussian Beam.

- In Summer 2004 the Main Injector was accelerating 6×10^{17} protons/week.

- The Mokhov calculation finds that we get 300 mrem for 3×10^7 protons/sec (1.81×10^{13} protons/week in our geometry. This is 3×10^5 of the accelerated beam.

- For the $\epsilon_V \approx 16\pi$ mm-mr, the beam size which includes all but 3×10^5 is about 18 mm at $\beta \approx 55$ m.

This would correspond to a pipe misalignment of 2.5 mm and an orbit error of 1.5 mm (injection plus closed orbit). Not a bad match to our typical bad locations. We conclude that small hot spots can be created by quite small fractions of the transmitted beams.

Details will be available (soon??) in

Beams-doc-1382 in the Accelerator (Beams) Division Document Database. http://beamdocs.fnal.g